| Project | IEEE 802.16 Broadband Wireless Access Working Group [http://ieee802.org/16](http://ieee802.org/16) |
| :---: | :---: |
| Title | Proposed SDD Text for DL OL SU-MIMO |
| Date <br> Submitted | 2008-09-05 |
| Source(s) | Hosein Nikopourdeilami, Mo-Han Email: <br> Fong, Jun Yuan, Sophie Vrzic, Robert  <br> Novak, Dongsheng Yu, Kathiravetpillai hosein@nortel.com <br> mhfong@nortel.com <br> Sivanesan  <br> Nortel Networks  <br> Serdar Sezginer, Bertrand Muquet, <br> Fabien Buda, Jeremy Gosteau <br> Sequans Communications jgosteau@sequans.com <br> Markus Muck  <br> Infineon MarkusDominik.Mueck@infineon.com |
| Re : | SDD Session 56 Cleanup, Call for PHY Details ; in response to the Call for Contributions and Comments on Project 802.16m System Description Document (SDD) 802.16m-08/033 for Session 57 |
| Abstract | This contribution proposes SDD text for DL OL SU-MIMO schemes |
| Purpose | For discussion and approval into TGm SDD text |
| Notice | This document does not represent the agreed views of the IEEE 802.16 Working Group or any of its subgroups. It represents only the views of the participants listed in the "Source(s)" field above. It is offered as a basis for discussion. It is not binding on the contributor(s), who reserve(s) the right to add, amend or withdraw material contained herein. |
| Release | The contributor grants a free, irrevocable license to the IEEE to incorporate material contained in this contribution, and any modifications thereof, in the creation of an IEEE Standards publication; to copyright in the IEEE's name any IEEE Standards publication even though it may include portions of this contribution; and at the IEEE's sole discretion to permit others to reproduce in whole or in part the resulting IEEE Standards publication. The contributor also acknowledges and accepts that this contribution may be made public by IEEE 802.16. |
| Patent <br> Policy | The contributor is familiar with the IEEE-SA Patent Policy and Procedures: <br> [http://standards.ieee.org/guides/bylaws/sect6-7.html\#6](http://standards.ieee.org/guides/bylaws/sect6-7.html%5C#6) and <br> [http://standards.ieee.org/guides/opman/sect6.html\#6.3](http://standards.ieee.org/guides/opman/sect6.html%5C#6.3). <br> Further information is located at [http://standards.ieee.org/board/pat/pat-material.html](http://standards.ieee.org/board/pat/pat-material.html) and [http://standards.ieee.org/board/pat](http://standards.ieee.org/board/pat). |

## Proposed SDD Text for DL OL SU-MIMO

Hosein Nikopourdeilami, Mo-Han Fong, Jun Yuan, Sophie Vrzic, Robert Novak, Dongsheng Yu, Kathiravetpillai Sivanesan

Nortel Networks
Serdar Sezginer, Bertrand Muquet, Fabien Buda, Jeremy Gosteau
Sequans Communications
Markus Muck
Infineon

## 1. Introduction

This contribution is to propose DL OL SU-MIMO scheme in response to C802.16m MIMO-08/005r1. We propose a 4Tx antennas rate 2 scheme to be included in the MIMO SDD RG document.

## 2. Multiplexing scheme with 4 TX antennas and rate 2

## Text Proposal modification to SDD

(L19, P68 of 003r4)

### 11.8.2.1.1. Open-loop SU-MIMO

| $N_{\mathrm{T}}$ | Rate | $M$ | $N_{\mathrm{F}}$ |
| :--- | :--- | :--- | :--- |
| $z$ | 4 | 4 | 4 |
| 2 | 1 | 2 | 2 |
| 4 | 4 | 4 | 4 |
| 4 | 1 | 2 | 2 |
| 8 | 4 | 4 | 4 |
| 8 | 1 | 2 | 2 |
| 2 | 2 | 2 | 1 |
| 4 | 2 | 2 | 1 |
| $\underline{4}$ | $\underline{\underline{2}}$ | $\underline{4}$ | $\underline{2}$ |
| 8 | 2 | 2 | 1 |
| $\underline{8}$ | $\underline{2}$ | $\underline{4}$ | $\underline{2}$ |
| 4 | 3 | 3 | 1 |
| 8 | 3 | 3 | 1 |
| 4 | 4 | 4 | 1 |
| 8 | 4 | 4 | 1 |

Table 5 Matrix dimensions for open-loop SU-MIMO modes
[modify section 11.8.2.1.1.1 of C802.16m-08/003r4 as follows]

### 11.8.2.1.1.1 Transmit Diversity

The following transmit diversity modes are supported for open-loop single-user MIMO:

- 2Tx rate-1: STBG」SFBC, and rank-1 precoder
- 4Tx rate-1: STBC/SFBC with precoder, and rank-1 precoder
- 8Tx rate-1: STBC/SFBC with precoder, and rank-1 precoder

In Transmit Diversity mode, the MIMO encoder generates 2Tx STBC/SFBC, and then multiplied by $N_{\mathrm{T}} \times 2$ matrix and $N_{\mathrm{T}} \times N_{\mathrm{T}}$ diagonal matrix as described in section 11.x.2.1.1.

For the transmit diversity modes, the input to the MIMO encoder is represented a $2 \times 1$ vector

$$
\mathbf{x}=\left[\begin{array}{l}
s_{1}  \tag{Equation11.x.2.1.1.1-1}\\
s_{2}
\end{array}\right] .
$$

The output of the MIMO encoder is a $2 \times 2$ matrix

$$
\mathbf{z}=\left[\begin{array}{cc}
s_{1} & -s_{2}^{*}  \tag{Equation11.x.2.1.1.1-2}\\
s_{2} & s_{1}^{*}
\end{array}\right] .
$$

For the 2 Tx rate- 1 mode, the output of the precoder is a $2 \times 2$ matrix

$$
\begin{equation*}
\mathbf{y}=\mathbf{z} \tag{Equation11.x.2.1.1.1-3}
\end{equation*}
$$

For the 4Tx rate-1, the output of the precoder is a $4 \times 2$ matrix

$$
\begin{equation*}
\mathbf{y}=\mathbf{D} \times \mathbf{W} \times \mathbf{z}, \tag{Equation11.x.2.1.1.1-4}
\end{equation*}
$$

where $\mathbf{W}$ is a $4 \times 2$ unitary precoder and $\mathbf{D}$ is a $4 \times 4$ identity matrix ( $D=I$ ). $4 \times 4$ diagonal phase matrix. Notethat $\mathbf{W}$ and $\mathbf{D}$ may be frequeney dependent as described in section 11.x.2.1.1.
$\underline{W}$ is a set of 6 antenna circulation matrices, i.e.,

$$
\mathbf{W}=\left[\begin{array}{ll}
1 & 0 \\
0 & 1 \\
0 & 0 \\
0 & 0
\end{array}\right],\left[\begin{array}{ll}
1 & 0 \\
0 & 0 \\
0 & 1 \\
0 & 0
\end{array}\right],\left[\begin{array}{ll}
1 & 0 \\
0 & 0 \\
0 & 0 \\
0 & 1
\end{array}\right],\left[\begin{array}{ll}
0 & 0 \\
1 & 0 \\
0 & 1 \\
0 & 0
\end{array}\right],\left[\begin{array}{ll}
0 & 0 \\
1 & 0 \\
0 & 0 \\
0 & 1
\end{array}\right],\left[\begin{array}{ll}
0 & 0 \\
0 & 0 \\
1 & 0 \\
0 & 1
\end{array}\right] .
$$

$\underline{\mathbf{W}}$ can be changed every pair of tones or symbols.

For the 8 Tx rate- 1 , the output of the precoder is a $8 \times 2$ matrix

$$
\begin{equation*}
\mathbf{y}=\mathbf{D} \times \mathbf{W} \times \mathbf{z}, \tag{Equation11.x.2.1.1.1-5}
\end{equation*}
$$

where $\mathbf{W}$ is a $8 \times 2 \underline{\text { unitary }}$ precoder and $\mathbf{D}$ is a $8 \times 8 \underline{\text { identity matrix }(~} \mathrm{D}=\mathrm{I}$ ) diagonal phase matrix. Note that $\mathbf{W}$ and $\mathbf{D}$ may be frequency dependent as described in section 11.x.2.1.1.
$\underline{\mathbf{W}}$ is defined as follows:

$$
\mathbf{W}=\mathbf{W}_{1} \times \mathbf{W}_{2}
$$

$\mathbf{W}_{1}$ is a $8 \times 4$ matrix which is implementation specific, $\mathbf{W}_{2}$ is a $4 \times 2$ unitary precoder which consists of a set of 6 antenna circulation matrices, i.e.,

$$
\mathbf{W}_{2}=\left[\begin{array}{ll}
1 & 0 \\
0 & 1 \\
0 & 0 \\
0 & 0
\end{array}\right],\left[\begin{array}{ll}
1 & 0 \\
0 & 0 \\
0 & 1 \\
0 & 0
\end{array}\right],\left[\begin{array}{ll}
1 & 0 \\
0 & 0 \\
0 & 0 \\
0 & 1
\end{array}\right],\left[\begin{array}{ll}
0 & 0 \\
1 & 0 \\
0 & 1 \\
0 & 0
\end{array}\right],\left[\begin{array}{ll}
0 & 0 \\
1 & 0 \\
0 & 0 \\
0 & 1
\end{array}\right],\left[\begin{array}{ll}
0 & 0 \\
0 & 0 \\
1 & 0 \\
0 & 1
\end{array}\right]
$$

$\mathbf{W}_{2}$ can be changed every pair of tones or symbols.
(L8, P70)

### 11.8.2.1.1.2. Spatial Multiplexing

[modify L10 to L14 of P70 of C802.16m-08/003r4 as follows]
The following spatial multiplexing modes are supported for open-loop single-user MIMO:

- Rate-2 spatial multiplexing modes:
o 2Tx rate-2: rate 2 SM
o 4Tx rate-2: rate 2 D-STTD and rate 2 SM with precoding
04 Tx rate-2: rate 2 SM with precoding
o 8Tx rate-2: rate 2 SM with precodingD-STTD and rate 2 SM with precoding
[Delete the content from L31 to L41in P70 and Insert the following text in the section 11.8.2.1.1.2 of 80216m08_003r4.]

For 4Tx antennas rate 2 mode, the input to the MIMO encoder is represented as a $4 \times 1$ vector (DSTTD case) or a $2 \times 1$ vector (SM case), i.e.

$$
\mathbf{x}=\left[\begin{array}{l}
s_{1} \\
s_{2} \\
s_{3} \\
s_{4}
\end{array}\right] \underline{\text { for DSTTD, } \mathbf{x}=\left[\begin{array}{l}
s_{1} \\
s_{2}
\end{array}\right]} \text { for SM }
$$

The output of the MIMO encoder is a $4 \times 2$ matrix (DSTTD case) or a $4 \times 1$ vector (SM case), i.e.

$$
\mathbf{z}=\left[\begin{array}{cc}
s_{1} & -s_{2}^{*} \\
s_{2} & s_{1}^{*} \\
s_{3} & -s_{4}^{*} \\
s_{4} & s_{3}^{*}
\end{array}\right] \text { for DSTTD, } \mathrm{Z}=\mathbf{x}=\left[\begin{array}{l}
s_{1} \\
s_{2}
\end{array}\right] \text { for SM }
$$

the output of the precoder is a $4 \times 2$ matrix (DSTTD case) or a $4 \times 1$ vector (SM case)

$$
\underline{\mathbf{y}=\mathbf{D} \times \mathbf{W} \times \mathbf{z}_{2}}
$$

where $\mathbf{W}$ is a $4 \times 4$ unitary precoder (DSTTD case) or a $4 \times 2$ unitary precoder (SM case) and $\mathbf{D}$ is a $4 \times 4$ identity matrix $(\underline{D=I})$.

When using Antenna Hopping with DSTTD, $\underline{\mathbf{W}}$ is a set of 3 antenna circulation matrices, i.e.,

$$
\mathbf{W}=\left[\begin{array}{llll}
1 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 \\
0 & 0 & 1 & 0 \\
0 & 0 & 0 & 1
\end{array}\right],\left[\begin{array}{llll}
1 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 \\
0 & 1 & 0 & 0 \\
0 & 0 & 0 & 1
\end{array}\right],\left[\begin{array}{llll}
1 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 \\
0 & 0 & 0 & 1 \\
0 & 1 & 0 & 0
\end{array}\right] .
$$

When using Antenna Hopping with $\mathrm{SM}, \underline{\mathbf{W}}$ is a set of 62 antenna circulation matrices, i.e.,

$$
\mathbf{W}=\left[\begin{array}{ll}
1 & 0 \\
0 & 1 \\
0 & 0 \\
0 & 0
\end{array}\right],\left[\begin{array}{ll}
0 & 0 \\
0 & 0 \\
1 & 0 \\
0 & 1
\end{array}\right],\left[\begin{array}{ll}
1 & 0 \\
0 & 0 \\
0 & 1 \\
0 & 0
\end{array}\right],\left[\begin{array}{ll}
0 & 0 \\
1 & 0 \\
0 & 0 \\
0 & 1
\end{array}\right],\left[\begin{array}{ll}
1 & 0 \\
0 & 0 \\
0 & 0 \\
0 & 1
\end{array}\right],\left[\begin{array}{ll}
0 & 0 \\
1 & 0 \\
0 & 1 \\
0 & 0
\end{array}\right] \dot{=}
$$

In DSTTD case, $\underline{\mathbf{W}}$ can be changed every pair of tones or symbols. In SM case, $\underline{\mathbf{W} \text { can be changed every }}$ tone or symbol.

For 8 Tx antennas rate2 mode, the input to the MIMO encoder is represented as a $4 \times 1$ vector (DSTTD case) or a 2 x 1 vector (SM case), i.e.

$$
\mathbf{x}=\left[\begin{array}{l}
s_{1} \\
s_{2} \\
s_{3} \\
s_{4}
\end{array}\right] \underline{\text { for DSTTD, }} \mathbf{x}=\left[\begin{array}{l}
s_{1} \\
s_{2}
\end{array}\right] \underline{\text { for SM }}
$$

The output of the MIMO encoder is a $4 \times 2$ matrix (DSTTD case) or a $4 \times 1$ vector (SM case)

$$
\mathbf{z}=\left[\begin{array}{cc}
s_{1} & -s_{2}^{*} \\
s_{2} & s_{1}^{*} \\
s_{3} & -s_{4}^{*} \\
s_{4} & s_{3}^{*}
\end{array}\right] \text { for DSTTD, } \mathrm{z}=\mathbf{x}=\left[\begin{array}{l}
s_{1} \\
s_{2}
\end{array}\right] \text { for SM }
$$

the output of the precoder is a $4 \times 2$ matrix

$$
\mathbf{y}=\mathbf{D} \times \mathbf{W} \times \mathbf{z}_{2}
$$

$\underline{\text { where } \mathbf{D}}$ is a $8 \times 8$ identity matrix $(\underline{D=I})$ and $\mathbf{W}$ is defined as follows:

$$
\mathbf{W}=\mathbf{W}_{1} \times \mathbf{W}_{2} .
$$

$\mathbf{W}_{1}$ is a $8 \times 4$ matrix which is implementation specific, $\mathbf{W}_{2}$ is a $4 \times 4$ unitary precoder (DSTTD case) or $4 \times 2$ unitary precoder (SM case).

When using Antenna Hopping with DSTTD, $\mathbf{W}_{2}$ is a set of 3 antenna circulation matrices, i.e.,

$$
\mathbf{W}_{2}=\left[\begin{array}{llll}
1 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 \\
0 & 0 & 1 & 0 \\
0 & 0 & 0 & 1
\end{array}\right],\left[\begin{array}{llll}
1 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 \\
0 & 1 & 0 & 0 \\
0 & 0 & 0 & 1
\end{array}\right],\left[\begin{array}{llll}
1 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 \\
0 & 0 & 0 & 1 \\
0 & 1 & 0 & 0
\end{array}\right] .
$$

When using Antenna Hopping with SM, $\mathbf{W}_{2}$ is a set of 6 antenna circulation matrices, i.e.,

$$
\mathbf{W}_{2}=\left[\begin{array}{ll}
1 & 0 \\
0 & 1 \\
0 & 0 \\
0 & 0
\end{array}\right],\left[\begin{array}{ll}
0 & 0 \\
0 & 0 \\
1 & 0 \\
0 & 1
\end{array}\right],\left[\begin{array}{ll}
1 & 0 \\
0 & 0 \\
0 & 1 \\
0 & 0
\end{array}\right],\left[\begin{array}{ll}
0 & 0 \\
1 & 0 \\
0 & 0 \\
0 & 1
\end{array}\right],\left[\begin{array}{ll}
1 & 0 \\
0 & 0 \\
0 & 0 \\
0 & 1
\end{array}\right],\left[\begin{array}{ll}
0 & 0 \\
1 & 0 \\
0 & 1 \\
0 & 0
\end{array}\right] .-
$$

C80216m-08_917r3
In DSTTD case, $\mathbf{W}_{2}$ can be changed every upair of tones or symbols. In SM case, $\mathbf{W}_{2}$ can be changed every tone or symbol.
[modify L1-L32 of P71of C802.16m-08/003r4 as follows]
For the rate- 3 spatial multiplexing modes, the input to the MIMO encoder is represented as a $3 \times 1$ vector

$$
\mathbf{x}=\left[\begin{array}{l}
s_{1}  \tag{Equation11.x.2.1.1.2-6}\\
s_{2} \\
s_{3}
\end{array}\right] .
$$

The output of the MIMO encoder is a $3 \times 1$ vector

$$
\begin{equation*}
\mathbf{z}=\mathbf{x} . \tag{Equation11.x.2.1.1.2-7}
\end{equation*}
$$

For the 4 Tx rate- 3 mode, the output of the precoder is a $4 \times 1$ vector

$$
\begin{equation*}
\mathbf{y}=\mathbf{D} \times \mathbf{W} \times \mathbf{z}, \tag{Equation11.x.2.1.1.2-8}
\end{equation*}
$$

 and $\mathbf{D}$ may be frequency dependent as described in section 11.x.2.1.1.
$\underline{\mathbf{W}}$ is a set of 4 antenna circulation matrices, i.e.,

$$
\mathbf{W}=\left[\begin{array}{lll}
1 & 0 & 0 \\
0 & 1 & 0 \\
0 & 0 & 1 \\
0 & 0 & 0
\end{array}\right],\left[\begin{array}{lll}
1 & 0 & 0 \\
0 & 1 & 0 \\
0 & 0 & 0 \\
0 & 0 & 1
\end{array}\right],\left[\begin{array}{lll}
1 & 0 & 0 \\
0 & 0 & 0 \\
0 & 1 & 0 \\
0 & 0 & 1
\end{array}\right],\left[\begin{array}{lll}
0 & 0 & 0 \\
1 & 0 & 0 \\
0 & 1 & 0 \\
0 & 0 & 1
\end{array}\right]
$$

W can be changed every tone or symbol.
For the 8 Tx rate- 3 mode, the output of the precoder is a $8 \times 1$ vector

$$
\begin{equation*}
\mathbf{y}=\mathbf{D} \times \mathbf{W} \times \mathbf{z}, \tag{Equation11.x.2.1.1.2-9}
\end{equation*}
$$



$$
\mathbf{W}=\mathbf{W}_{1} \times \mathbf{W}_{2}
$$

$\mathbf{W}$ is $a \times 3$ precoder and $\mathbf{D}$ is $a 8 \times 8$ diagonal phase matrix. Note that $\mathbf{W}$ and $\boldsymbol{D}$ may be frequency dependent as described in section 11.x.2.1.1.
$\mathbf{W}_{1}$ is a $8 \times 4$ matrix which is implementation specific, $\mathbf{W}_{2}$ is a $4 \times 3$ unitary precoder which consists of a set of antenna circulation matrices, i.e.

$$
\mathbf{W}_{2}=\left[\begin{array}{lll}
1 & 0 & 0 \\
0 & 1 & 0 \\
0 & 0 & 1 \\
0 & 0 & 0
\end{array}\right],\left[\begin{array}{lll}
1 & 0 & 0 \\
0 & 1 & 0 \\
0 & 0 & 0 \\
0 & 0 & 1
\end{array}\right],\left[\begin{array}{lll}
1 & 0 & 0 \\
0 & 0 & 0 \\
0 & 1 & 0 \\
0 & 0 & 1
\end{array}\right],\left[\begin{array}{lll}
0 & 0 & 0 \\
1 & 0 & 0 \\
0 & 1 & 0 \\
0 & 0 & 1
\end{array}\right]
$$

$\mathbf{W}_{2}$ can be changed every tone or symbol.

For the rate- 4 spatial multiplexing modes, the input to the MIMO encoder is represented as a $4 \times 1$ vector

$$
\mathbf{x}=\left[\begin{array}{l}
s_{1}  \tag{Equation11.x.2.1.1.2-10}\\
s_{2} \\
s_{3} \\
s_{4}
\end{array}\right]
$$

The output of the MIMO encoder is a $4 \times 1$ vector

$$
\begin{equation*}
\mathbf{z}=\mathbf{x} . \tag{Equation11.x.2.1.1.2-11}
\end{equation*}
$$

For the 4 Tx rate- 4 mode, the output of the precoder is a $4 \times 1$ vector

$$
\begin{equation*}
\mathbf{y}=\mathbf{z} \tag{Equation11.x.2.1.1.2-12}
\end{equation*}
$$

For the 8 Tx rate- 4 mode, the output of the precoder is a $8 \times 1$ vector

$$
\begin{equation*}
\mathbf{y}=\mathbf{D} \times \mathbf{W} \times \mathbf{z}, \tag{Equation11.x.2.1.1.2-13}
\end{equation*}
$$

where $\mathbf{W}$ is a $8 \times 4$ precoder which is implementation specific, and $\mathbf{D}$ is a $8 \times 8$ identity matrix ( $\mathrm{D}=\mathrm{I}$ ) diagonal phase matrix. Note that $\mathbf{W}$ and $\mathbf{D}$ may be frequency dependent as described in section 11.x.2.1.1.

